

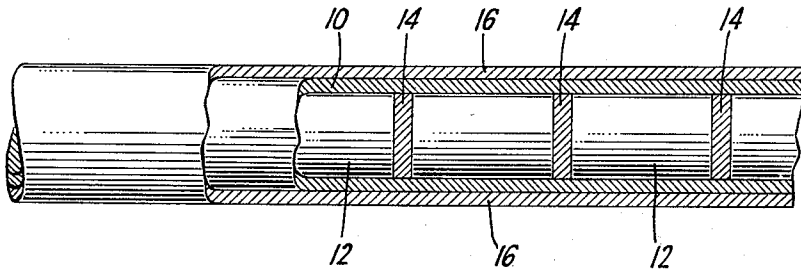
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L. W. KATES ET AL

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METHOD FOR MAKING FUEL ELEMENTS

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INVENTORS
LEONARD W. KATES
ROBERT W. CAMPBELL
RAYMOND H.W. HEARTEL
BY
F. Kump
ATTORNEY

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METHOD FOR MAKING FUEL ELEMENTS

Leonard W. Kates, Hempstead, and Robert W. Campbell, Malverne, N.Y., and Raymond H. W. Heartel, Cranford, N.J., assignors, by mesne assignments, to the United States of America as represented by the United States Atomic Energy Commission

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1 Claim. (Cl. 29—528)

This invention relates to a method for making fuel elements. More particularly, it relates to a method for making fuel elements for a nuclear type reactor.

Many types of fuel elements have been devised and developed for use in nuclear reactors. Among these are the so-called wire plate and ribbon types. The wire type has an advantage over the other types in that it has a very large ratio of surface area to volume of fuel element. Although methods have previously been devised for making this wire type fuel element none of the prior art methods heretofore used have lent themselves to the manufacture of wire-like or ribbon type fuel elements of a desired length, that is to say, none of the heretofore used methods are adapted to make desired lengths of this fuel element in a commercial manner which require no further fabrication.

It is, therefore, an object of this invention to provide a method of making fuel elements of any desired length by a commercially practical method.

It is a further object of this invention to provide a simple method for making the wire type fuel elements which will permit the manufacture of an indefinite number of predetermined lengths of wire in a continuous manner. It is another object to make cored wire with uncured ends for fastening or joining without necessity of welding or otherwise fabricating the cored material itself.

It has been found that these objects and other advantages incidental thereto can be attained in accordance with this invention.

In the drawings which illustrate features of this invention Figure 1 is a sectional elevation showing the component parts of the fuel element in the initial stages of its fabrication.

In accordance with this invention it has been found that wire-like, or ribbon-like fuel elements of predetermined lengths can be attained in a commercial manner by introducing measured quantities of core material into a hollow tube whose cross section is not necessarily round and which is made of cladding material by alternately introducing measured quantities of core material and a plug made up of these same compositions as the cladding material into a hollow tube of clad material and sealing off the ends of the hollow tube, drawing or otherwise working the clad tubing down into the desired dimensional size and finally cutting the wire so formed into the desired lengths by cutting through those sections where the plug material is present.

The assembly of these components is most aptly shown in Figure 1 of the drawings where 10 indicates the hollow tube of cladding material, 12 the core material, 14 the plugs which have been inserted between the measured quantity of core material and 16 a protective sheathing material which may be used during the actual working down of the metal into its wire form.

The components which go into making the wire-like fuel elements of this invention can naturally be the same

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type metals which are normally used in making fuel elements for nuclear reactions. The cladding material 10 should naturally be made out of a corrosion resistant metal since different types of nuclear reactors operate under different conditions and with the use of different cooling mediums the material used for this purpose can of course vary over a rather wide range. In the so-called slow type reactor the preferred material to be used is normally one having a low neutron absorption cross section and which is corrosion resistant to water and air. For this purpose metal such as zirconium, beryllium and aluminum are preferred examples. In the faster reactors metals having a higher neutron absorption cross section may be used. Stainless steel is a good example of such material. The important characteristic of course is the metals corrosion resistance.

The specific core material which is to be used in making these wire type fuel elements is also not of any particular or significant importance. Any one of the substances which is normally used for this purpose such as uranium or its alloys would lend themselves to the making of fuel elements in accordance with this invention.

The metal which is used to make the sheathing material 16 must, of course, be one which is chosen because of its characteristics. Its function is to prevent the oxidation of the cladding material during the processing of the composite that is during the rolling, swaging or drawing operations during which the wire or ribbon is being formed. This material must be one which can withstand rather high temperatures but one which will not enter into a reaction with the cladding material so that at the temperatures at which the material is worked it neither alloys therewith nor forms brittle mixtures which will make it impossible to work the metal into the desired shape and form. The metal should, furthermore, be relatively cheap and one which can readily be removed from the cladding material by physical or chemical means. A good example of such material is cold rolled iron particularly when zirconium or zirconium alloy is used as the cladding material. In many of these cases the iron can be removed by dissolving it in an acid solution such as a 50% nitric acid solution.

The essential features of this invention are, of course, the use of measured quantities of the core material interspersed between plugs of the cladding material within the tubular cladding material itself. When the sheath components have been prepared in the manner illustrated in Figure 1 and either rolled, swaged or drawn down to the desired size the resulting structure is a continuous wire or ribbon which has alternate cores of fissionable material and separated by plugs of the cladding metal. The long single piece of wire can then be cut up into such lengths so that each individual piece will only contain one section of fissionable material as its core and which fissionable core material will be completely surrounded by cladding metal both at its side and at the end. This, of course, can be accomplished by cutting the wire or ribbon at those points at which the clad material plugs the wire or ribbon. If equal amounts of fissionable or core material were placed between the individual plugs which went to make the original composite piece it will be possible to obtain similar size pieces of wire or ribbon in which the core material is completely surrounded by the metal formed by cutting the finished wire at those places at which the plugs separate one section of core material from the other.

The actual determination as to where to cut the finished wire or ribbon to obtain the desired lengths can of course be accomplished by the trial and error procedure. However, a much simpler and better method is to make use of radiographic equipment for inspecting the wire. With the use of this equipment it is readily possible to deter-

mine at which points in the wire or ribbon are the plugs and which points contain the core material.

In those cases in which the core material is sufficiently active to energize a simple counter this device could of course be used for the same purpose.

By this means it is therefore readily possible to cut the wire at the desired point selected as a result of the radiographic inspection thus making it possible to cut the wire at only those points at which the active core material will be completely surrounded by the cladding metal.

In assembling the components of the wire preparatory to working it to form the wire by swaging or drawing it is preferable to take steps to make certain of a good bond between the core material and the cladding, if best results are to be obtained. In order to insure a good snug fit it has been found desirable to make a so-called sweat fit between the core material and the cladding material. This can be accomplished by chilling the core material in Dry Ice or in Dry Ice in acetone and then inserting it into the tube of cladding material after which the plug materials are inserted and the whole composite is allowed to come up to temperature at which time the core material will expand and make a snug fit with the cladding material. To accomplish this it is of course necessary that the inside diameter of the cladding material and the outside diameter of the core are of suitable dimensions to make this method of assembly necessary and workable.

The following is an illustrative example of a method of making a wire in accordance with this method. A tube of zirconium or one of its alloys having good corrosion resistant properties and having an outside diameter of about $\frac{1}{2}$ " and an inside diameter of about .250" is plugged at one end with a piece of zirconium of the proper size after which a slug of core material such as, for example, uranium having an outside diameter of .250" after having been cooled in Dry Ice is introduced into the tubular zirconium. This is followed with a piece of clad material to form a plug at the top of the core material after which a second section of the cooled core material is placed on top of the plug. This is again followed with a plug and a third section of cooled core material of size similar to the first two. This operation is continued with alternate sections of core material and plugs until the entire tube of cladding material 10 has been filled and the plug 14 has been inserted at its outer end. The cored tubulation is then sheathed in a sheathing material such as iron for example whereupon it is ready to be worked to form the wire or ribbon of the desired gauge or size. To obtain best results the working is usually carried on at temperatures lying within the range of 800 to 900° C. However, temperatures as low as 600° C. might also be used. It is, however, best not to exceed 900° C. particularly when using iron as the sheath material and zirconium as the cladding material, since above these temperatures the iron and zirconium will alloy to form a brittle eutectic mixture.

When the composite is held within a temperature range of about up to 900° C. it can readily be worked either by swaging or drawing to form wire of the desired dimensional characteristics. Naturally some composite materials can be worked more readily than others. The determining factor is, of course, the ductility of the met-

als being used. With the more ductile materials it is entirely possible to swage the composite all the way down to the wire and still obtain a material of good quality, that is one in which the core material is centrally located and is present in the form of a substantially perfect cylinder. However, when the cladding material is less ductile it is preferred that the working be done for the most part by drawing the composite through round dies. In this manner it is more readily possible to hold the material to the desired quality.

After the material has been worked to the desired dimension the sheathing material can be removed. This is preferably done by some chemical means. In the case of iron with a zirconium cladding material the iron can readily be removed by dissolving it in dilute nitric acid of about 50% nitric acid in water. By this means the iron will be dissolved but the zirconium will be intact.

The dimensions of the finished product will of course depend on the amount of working that takes place. It is readily possible, for example, to obtain wires having an outside dimension of .080" and with a core diameter of .040".

When this wire is obtained it is subjected to radiographic inspection which indicates the plates at which the plug material separates the fissionable core material from the next succeeding core of fissionable material, whereupon the wire is cut at these points where the plug is present thus yielding as a final product equal lengths of a wire-type fuel element completely surrounded by a cladding metal. The material thus obtained requires no further fabrication to seal in the core material.

While the above description and drawings submitted herewith disclose a preferred and practical embodiment of the fuel element of this invention it will be understood that the specific details of construction and arrangement of parts as shown and described are by way of illustration and are not to be construed as limiting the scope of the invention.

What is claimed is:

The method of manufacturing a nuclear fuel element in the form of a wire having a core containing fissionable material in close contact with a cladding metal that comprises the steps of plugging one end of a hollow tube of zirconium with a plug made of zirconium, chilling a slug of uranium in Dry Ice, introducing the chilled uranium slug into the zirconium tube to rest against the plug, introducing a second zirconium plug into the tube and in contact with the chilled uranium slug, inserting additional chilled uranium slugs and zirconium plugs alternately into the zirconium tube until the entire length of the tube is filled, permitting the chilled uranium plugs to attain room temperature, whereby the uranium will expand into close contact with the zirconium tube, inserting the filled tube in an iron sheath, working the sheathed tubing at a temperature in the range of 600° to 900° C. to form a wire of predetermined diameter, and thereafter removing the sheath.

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